HISTOLOGY AND METHODS OF INSTRUCTION.

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In the preface to the first edition of his *Handbook of Human Histology*, Kölliker made this significant remark: "Medicine has reached a point at which microscopical anatomy seems as necessary for a foundation to it as does the gross anatomy of the organs and system; and when a profound study of physiology and pathology is impossible without an exact knowledge of the finest structural details." If this was in the main correct in 1852, when Kölliker first wrote it, how much more is it so at the present day when not only medicine, but the great science of biology is taking such a prominent position in the minds of men. Indeed, in its broad aspect medicine is but one of the details of biology, and pathology is biological activity perverted by abnormal influences and environment; and since the time when Virchow's cellular pathology appeared, it has been known that the real seat of this perverted activity resides in the microscopic elements or cells which compose the different organs and tissues. Likewise is it known with the greatest certainty that all normal activity goes on in the microscopic elements making up the tissues; and finally the germs of a new generation, the bearers of heredity by which the past reappears in the future, are likewise, in most cases, microscopic elements. In a word, without the microscope, knowledge would be turned back a century and the certainty concerning many things in biology today would give place to the baseless speculations of the dark ages.

All teachers of histology have, of course, the same general object in view, viz.: to give their pupils a knowledge of the

microscopic structure of the body. Naturally, and of necessity the way in which different teachers go to work to give their pupils this knowledge will depend on the teacher's view as to the special end to be attained by the study, and secondly on the facilities he has at his disposal. The views expressed in this paper may not accord with those of teachers, in whom experience and special surroundings have given rise to fixed convictions, but it is hoped that some of the younger teachers may get suggestions from it that will aid them in making the most of their surroundings and facilities ; it is hoped also that the subject of histology will be seen by them to be vitally important for an understanding of physiology, morphology and pathology. It is hoped also that the end of histology will not seem to any to be reached when an organ or tissue has been fixed, hardened, cut with an expensive microtome, stained in brilliant colors and finally embalmed in Canada balsam. It is hoped rather that all of this labor and pains may be seen to be only to help one see the physiologic, morphologic or pathologic processes and relations exhibited by the tissue more clearly. If the microscopic preparations have no such meaning to the student then they are no better than so many Chinese puzzles.

It seems to the writer that the first step in histology is a thorough study of the chief instrument used, the microscope. The microscope is to aid the eye in seeing what is invisible or not satisfactorily visible without it, and unless one knows something of the methods of making this helper to vision a real helper, much time will be wasted. This is especially true of the better forms of instruments. One can use with some satisfaction a simple magnifier without instruction or much study, but a good modern, compound microscope to be of much use must be well understood ; one must know its possibilities and limitations. It seems to the writer that time is really saved for histology by devoting a few weeks to the microscope itself, and to the methods of micrometry, drawing, the use of the micro-polariscope, the micro-spectroscope and other accessories. Otherwise one must learn

these things when he is trying to make use of them in solving some problem in actual work.

It may naturally be asked what kind of a microscope is necessary for the pursuit of modern histology? While a great deal of excellent work may be done with comparatively inexpensive apparatus, costing from $25 to $50 and magnifying from 25 to 500 diameters, one cannot follow out the finer details in histology and pathology with such an outfit, and in some parts of pathology, where bacteria are involved, one would be practically helpless. Some such outfit as the following seems necessary: Dry objectives of 50 mm. (2 in.), 16 mm. ($\frac{2}{3}$ or $\frac{3}{4}$ in.), and 3 mm. ($\frac{1}{8}$ in.), and a homogeneous immersion of 2 mm. or $1\frac{1}{2}$ mm. (1-12 or 1-16 in.) There must be some form of substage condenser. This, like the objectives, will serve one in proportion to its excellence. The stand of the microscope should have a coarse and fine adjustment for focusing, the pillar should be flexible, so that it may be used in either the vertical or inclined positions, and the substage should have a rack and pinion adjustment for the substage condenser, and an arrangement for centering. Fortunately such an outfit can be had at the present day for less than $100, if supplied with ordinary achromatic objectives; but the cost is much greater if the best achromatic or apochromatic objectives are obtained. It is of the greatest advantage also to have a mechanical stage of some sort. The removable mechanical stages after the Tolles-Mayall pattern are inexpensive and most satisfactory.

For laboratory work there are two methods, the one allowing students to come at their convenience and accomplish as much work as they can or wish to. The other plan is to give a medium amount of work, which must be accomplished in a given time. The students are required also to come in regular sections. The last way seems to the writer the best. Experience has shown that regular sections, in which the teacher devotes his whole time to the laboratory, yield better results. There is a kind of momentum gained in this way that overcomes the inertia of the less energetic,

and for those that get through with the small amount of work that must be assigned for a lesson there is abundant opportunity to consult monographs and go more deeply into the subject than is required of the average student. To conduct a class in this way, however, necessitates abundant, well-lighted space, plenty of tables and microscopes, and other laboratory facilities. It can be readily seen that laboratory work in histology carried on in this way requires an expensive plant. If the subject is to be taught at all, this is the only economical way, however. To keep a laboratory open all day and every day, the teacher being on duty all the time, is wasteful and the results unsatisfactory ; as unsatisfactory and uneconomical as it would be to divide a Greek class of twenty up into five to ten sections for recitation. The last section would hardly gain much inspiration from the teacher, and such a teacher would not be likely to add much to comparative philology or anything else.

In the actual instruction it is believed that there should be a combination of lectures and laboratory work. The lectures serve to give the students broad and general ideas and the relations of the subjects to each other ; that is, they give the fundamental facts, principles and relations, which are the result of the investigations of the best workers. The best books and monographs are referred to and shown, and put at the students' disposal. This is done because it is believed that every one should take advantage of the gain made by his predecessors and not try to start at the beginning. Life is too short for that, and progress would almost or quite cease if the gain made by our predecessors could not be made use of. From a long observation it is believed that the student who has the power to make independent investigations should have these helps, so that he may recognise the attainments of others and start from their vantage ground to explore new fields. For the student who has not the power for original investigation this is the only way to help him. He cannot go where there is no path.

In the second place there should be abundant opportunity

for laboratory work where the student is brought into direct contact with the truths of nature in nature herself, and if he is an honest man he must work very hard to make out these truths, no matter how much help he has been given by lectures and books.

In the laboratory work each student should learn and practice all the principal methods. A preparation made by the student himself from getting the tissue until it is mounted and labeled means something to him ; it is connected in a very definite way with the organ or part in the animal. He also gains skill in manipulation, and without skill in manipulation no real progress can be made in any science. Exact notes, with dates and drawings, are necessary to avoid vagueness and to prevent the student from deceiving himself in the belief that he has gained certain knowledge when he has not. These notes and drawings, and the students' specimens, duly labeled and catalogued, should be most conscientiously scrutinised by the teacher. They give him an opportunity that nothing else can to help the student by correcting erroneous conclusions and by aiding him in gaining skill in manipulation. It may well be asked, however, if it is possible to get a class through the tissues and organs of the animal body by having each student perform all the operations for himself. It is admitted that the time necessary would be too long, and for most of the students much time would be unnecessarily used in mere mechanical operations. The plan advocated is to have each student learn all the fundamental processes in modern histology, and learn them by repeated operations, but the loss of time by mere repetition after the processes have been mastered may be avoided without injury by furnishing most of the preparations either already cut or imbedded ready for cutting. It is believed that every preparation, with rare exceptions, should be in part at least, the work of the student. If then for these partly prepared preparations full data are given concerning the methods used the student will have no trouble in making the proper connection mentioned above when he performed

all the work himself. It is believed that the ground can be covered in this way and it is known from experience and observation that the intellectual independence gained by the personal work of each student will repay all trouble on the part of the teacher—for it is more trouble to guide the student than for the teacher to do the work himself. The student will gain also the power to use the work of others, and to judge it at its true value as he could in no other way.

In the actual work carried on by the writer, lectures are given to the entire class, and, then, for the laboratory work sections of about fifteen are taken for not less than two hours at a time. If a period of less time were given, so much of it would be used in getting ready to work and in clearing up that not enough actual, productive work could be done to repay the effort. Each student is given the use of a locker ; each one prepares nearly all of the reagents used by him, and each one learns the methods of isolation, of sectioning by the collodion and by the paraffin method, both with simple and inexpensive and by the best modern apparatus ; and all have opportunity to see the method of making frozen sections, so largely used in diagnosis in pathological work. There is a large cabinet of specimens illustrating microscopy, histology and embryology, made and labeled and catalogued with all possible care, to serve as models for the students and for reference. The cabinet has been found very valuable for stimulating independent work. If one sees only figures of microscopic objects he may feel that to make actual specimens which shall show the objects with equal clearness would be impossible for a student, but if such specimens are at his disposal he is stimulated and encouraged to prepare similar ones for himself. He soon learns also, in studying actual specimens, that many of the figures in the books are composites,—made by combining the best features of several preparations.

For convenience, the animal body is divided into the following groups of tissues and organs. The arrangement is

more or less logical also on embryologic, physiologic and morphologic grounds :

1. Epithelia, including endothelia.
2. Connective and supporting tissue (Areolar tissue, tendon, ligament, bone, cartilage, etc.).
3. The muscular system.
4. Blood and lymph, *i. e.*, the fluids of the body and their corpuscles.
5. The blood and lymph vascular system.
6. The digestive system.
7. The respiratory system.
8. The genito-urinary system.
9. The skin and its appendages.
10. The nervous system and the organs of sense.

In teaching, the following guiding principles have been followed :

1. It has always seemed to the writer that one of the most important steps in the knowledge of the structure of the tissues and organs is a thorough knowledge of the gross anatomy. The histologist must, first of all, be a thorough naked-eye anatomist. He must also be a physiologist, and he will naturally become an embryologist, for without the knowledge that embryology gives, the adult structure is frequently unintelligible, and without physiology, structures are, in many cases, meaningless. The wise histologist is then a physiologist, an embryologist and an anatomist. From the naked-eye appearances he passes as necessity requires, from the contemplation of organs and tissues, first to a low power and then for the finer and finest structural details to the highest powers available. But he never loses sight of the fact that the details alone are far less intelligible than when they are correlated with the organ or tissue to which they belong.

2. It seems so natural and logical in teaching the fundamental facts concerning the morphology and structure of the body to refer to the mode of development, that for several

years the students have not only been taught in lectures from the embryological standpoint, but each student in the beginning has put into his hands, in the laboratory, preparations of the ovarian ovum to represent not only a typical cell, but the fundamental fact that the complex body of the largest animal is derived from the ovum. Then preparations of the blastula with a single layer, representing in a general way a simple epithelium, are studied, and then the blastula with a wall several cells thick, representing in general a stratified epithelium. Other preparations are studied, showing clearly the mode of formation of the axon or notochord from the entoderm, and of the neuron or central nervous axis from the ectoderm. After studying these preparations it means something to the student when he reads or hears in lectures that a given tissue or organ is derived from one or the other of the germ layers.*

3. Each tissue is studied fresh, so that correct notions may be gained of the natural appearance of the organs and tissues and their structural elements unaffected by reagents.

4. Every organ and tissue is studied alive, so far as possible, in order that the function and the structure that performs the function may be seen at the same time and the two properly associated. Students who see only prepared specimens can hardly avoid gaining the impression that the gorgeous red, blue and purple colors belong to the natural tissues, and would be so found in dissecting an animal. Indeed the histologist who studies his subject profoundly looks upon the adjuncts of stain, etc., as necessary evils at best, and he never feels quite sure that the appearances seen in these much-stained and manipulated specimens are true expressions of nature, or whether they are structures of his own creation (artifacts), until he has seen the appearances in the living substance, where the pitfalls of color and Canada

* The preparations used in my laboratory are the small ovarian ova found in the ovary of a young *Amblystoma*, or those left after spawning. All sizes are seen, giving also a hint that the different sizes mean the different crops of eggs, so to speak, that will reach maturity. The segmenting ova of *Amblystoma* are admirable for showing the blastula, and the formation of notochord and nervous system.

balsam have no place. (See the preface to *Foster and Langley's Practical Physiology.*)

5. All glands should be studied in various phases of their activity and repose, so that the structural features present in each phase may be associated with the functional condition. In a word, it is greatly to the advantage of the student if the histology he studies is truly "Physiological Histology."

6. The student will gain a truer insight into the structure of the body if he understands at the beginning that every organ and every tissue as it is found in the body is really a complex ; that is, it is composed of several tissues and of ground substance. For example, muscle is composed not only of the characteristic structural elements, the muscle fibers or cells, but mingled with these are connective tissue and blood vessels, and nerves are abundant. Even in epithelium the cells are not the whole of the tissue, for there is always present the cell cement uniting the cells. In connective tissue, the characteristic elements or cells, so prominent in this tissue in embryonic life, are so far pushed into the back-ground by the intercellular or ground substance, that the tissue is actually characterised, not by the cells, but by the ground substance. Thus we speak of cartilage, ligament and bone and the other members of the connective tissue group, having in mind almost altogether the intercellular substance, and not the cellular elements.

7. Of necessity, as well as preferably, every general course in histology must be a course in *comparative histology*, as structural details are not all shown with equal clearness in any one form and not obtainable at all, or only with difficulty in some. For example, hair is not found below the mammals, and the fibrin network in the blood and lymph is far more satisfactory in man and the other mammals than in *Amphibia* and fishes, while nucleated red blood corpuscles are found with difficulty in mammals, while they are normal in non-mammals. As the course is then to be really one in *comparative histology*, the fact should be distinctly expressed, and the student not left to infer that a structural detail seen

in one animal would be found exactly similar in all others. On the other hand, it should be most emphatically brought out that *while there is unity in type there is much diversity in detail.* This can be demonstrated by each student in comparing the striated muscle of mammals and *Amphibia ;* or to take nearly related forms, the *ligamentum nuchæ* of the ox and other grazing forms is almost purely elastic tissue, while in the cat and man it is largely white fibrous tissue, and far less prominent. This point has been insisted upon, because if any one looks through the pages of any work on histology, even though "human histology" may be printed on the title page, he will find it really a comparative histology, with the comparisons left out. That is, there will be figures of structures from widely differing animals to illustrate the structure of the different tissues, and frequently even the accompanying legend or explanation gives no hint that the tissue figured is not from man. Naturally the student concludes that the tissues are exactly alike in all animals. If on the other hand homologous parts from different animals are carefully compared many of them will show marked differences in detail, although the type of structure is unmistakable.

8. If it is necessary to keep in mind the differences in anatomic details in different animals, so is it equally important to know and to learn to demonstrate differences in structural detail of the same tissue or organ in the same animal in different phases of activity, in vigorous youth and in senile decay. Indeed, the differences in structural appearance of the pancreas, for example, before and after secretion, is as great as the apparent structural differences in quite widely differing forms. It is, therefore, necessary for a complete understanding of structural appearances to keep physiology constantly in mind ; and as so few animals are in perfect health, possible pathologic variations from the normal appearance must be looked out for, otherwise one might in a limited number of observations decide that merely temporary or even abnormal structural appearances were characteristic of the animal under investigation.

The above statements, while they apply to the study of histology in general, have special reference in the main to elementary courses, where the students are introduced to the subject and are naturally imbibing the spirit of the study.

The course outlined above would require considerable time. It could not be satisfactorily gone over in less than one college year, in a course consisting of two lectures per week and three laboratory periods of two and one-half hours each.

For research in this, as in any other subject, there must be great liberty as well as good facilities for work and experimentation. Mistakes will be made and time apparently wasted ; but the mistakes and the apparent waste of time are a part of the "dead work" that must be done by all those who aspire to perform truly advanced work and to add to the sum of human knowledge.

Besides the numerous addresses and special papers that have appeared the student and teacher will find the six books named below especially helpful and inspiring :

An American Text-Book of Physiology. Edited by Wm. H. Howell, of Johns Hopkins. The writers besides the editor are : H. P. Bowditch, J. G. Curtis, H. H. Donaldson, F. S. Lee, W. P. Lombard, G. Lusk, W. T. Porter, E. T. Reichert and H. Sewall. Philadelphia. 1896.

Bernard, Claude, Cours de physiologie générale du Muséum d'histoire Naturelle. Leçons sur les phénom nes de la vie communs aux animaux et aux végétaux, two vols. Paris. 1878-1879.

Foster, M.—A Text-Book of Physiology (1877 to 1896). London and New York. The sixth edition contains much histology. All the editions correlate structure and function in an admirable way.

Metchnikoff, Elias—Lectures on the comparative pathology of inflammation, delivered at the Pasteur Institute in 1891. Translated from the French by F. A. and E. H. Starling, London. 1893.

Hertwig, O.—The Cell ; Outlines of General Anatomy and Physiology. Translated and edited by M. and H. J. Campbell. London and New York. 1895.

Wilson, E. B.—The Cell in Development and Inheritance. Columbia University. Series IV. New York and London. 1896.

For an excellent article on The Importance of Technical Instruction in our Medical College Laboratories, see Dr. A. P. Ohlmacher, *New York Medical Record*, Vol. LXIII., March 21, 1896, p. 374.

For a view that all microscopical and bacteriological knowledge is of no assistance in either medicine or biology, see Dr. Charles G. Kuhlman, in the *St. Louis Medical and Surgical Journal*, Vol. LXX. April, 1896, p. 201.